

## **Estimating Winds and Waves from Synthetic Aperture Radar under Typhoon Conditions**

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### **LONG-TERM GOALS**

The long term goals of this project is to develop a typhoon SAR wind algorithm for C-Band which also can be modified to be applied to X-Band and L-Band SAR data.

### **OBJECTIVES**

We begin with a multi-pronged approach that will include up to three different SAR wind and wave algorithms to be validated with in-situ observations and accurate model predictions during typical hurricane and typhoon conditions. The next step will be to modify these algorithms to allow both SAR data from L-band and X-band systems.

The specific scientific objectives of this study are and will be performed in collaboration with Dr. C. Wackerman, General Dynamics Advanced Information Systems, and Dr. J. Horstmann, NATO-NURC, LaSpezia, Italy:

1. To determine how accurately C-band wind algorithms can measure the wind vector field in tropical cyclones such as hurricanes and typhoons.
2. To determine how accurately C-band wave algorithms can measure the properties of directional wave field in tropical cyclones such as hurricanes and typhoons.
3. To examine how these winds and wave algorithms could be extended to perform for SAR data from L-band and X-band systems.
4. To determine a test data set of ground truth based on in-situ and airborne observations as well as highly accurate model predictions.
5. To develop performance metrics that provides error statistics.

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## **APPROACH**

### **Modification of CSTARS Wind Vector Tools**

CSTARS has implemented and operates two wind algorithms. The APL/NOAA SAR Wind Retrieval System (ANSWRS) developed by the Johns Hopkins University Applied Physics Laboratory (JHU/APL) that is currently being used for near real-time wind field retrievals at NOAA, JHU/APL, ASF, and CSTARS. The second algorithm is WiSAR, formerly from GKSS and now from NATO/NURC which is one of the most advanced algorithms for wind vector retrieval from SAR image features. The algorithm was developed by Horstmann et al., which yields a wind speed and direction accuracy of 1.6 m/s and 20° (Horstmann et al., 2000; 2003). The wind direction retrievals are made at 6-km intervals and the wind speeds computed on a pixel level with wind directions interpolated down to the pixel location. At CSTARS the wind vector retrievals are made at 1 km spacing for better resolution of the hurricane wind field and using features in the image to retrieve the wind direction at scales as small as just a few hundred meters. This advanced SAR algorithm has been running operationally at CSTARS for the past three hurricane seasons.

### **Modification of CSTARS Wave Spectra Tool**

CSTARS has been experimenting with a simple SAR wave height extraction tool based on the DLR model (Schulz-Stellenfleth and Lehner, 2004; Niedermeier et al., 2005). Another model CSTARS is considering is the BOOST model. One of the advantages of the BOOST model is that it works both for image mode and wave mode on ENVISAT and ERS-2 data and also utilizes polarization. In particular, a new treatment of the non-linear intrinsic SAR imaging mechanism and non wave signatures (inhomogeneities caused by low wind conditions, internal waves, rain, land contamination...) have been developed. Such improvements helped to gain both in processing speed and applicability to all radar configurations and environmental conditions.

To test the new typhoon wind algorithm, CSTARS will use the RadarSat-1 and ENVISAT ASAR data sets of hurricane and typhoon images which were collected over the past five years.

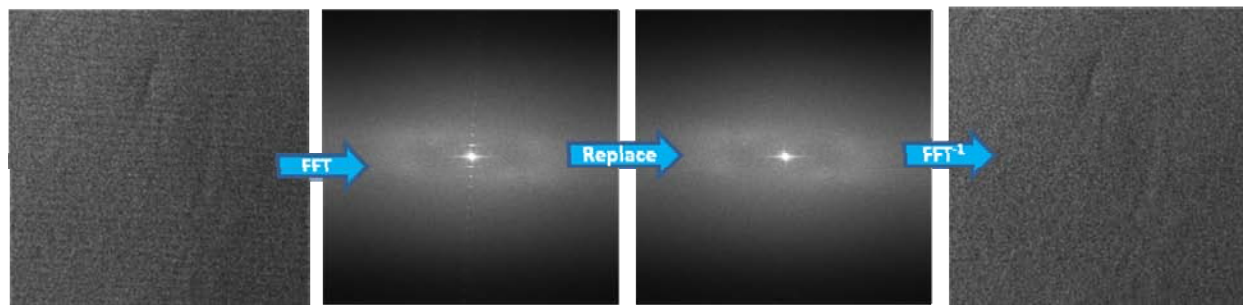
## **WORK COMPLETED**

- 1) Hosting of extensive RadarSat-1 and ENVISAT ASAR data of hurricanes and typhoons.
- 2) Implementation of three different wind and wind extraction algorithms at CSTARS.
- 3) Testing of wind algorithms for near real time product generation.
- 4) Test of wave algorithms with SAR data.
- 5) Completion of a scalloping filter.
- 6) Participation in three workshops.
- 7) Developing backbone for typhoon wind algorithm.

## **RESULTS**

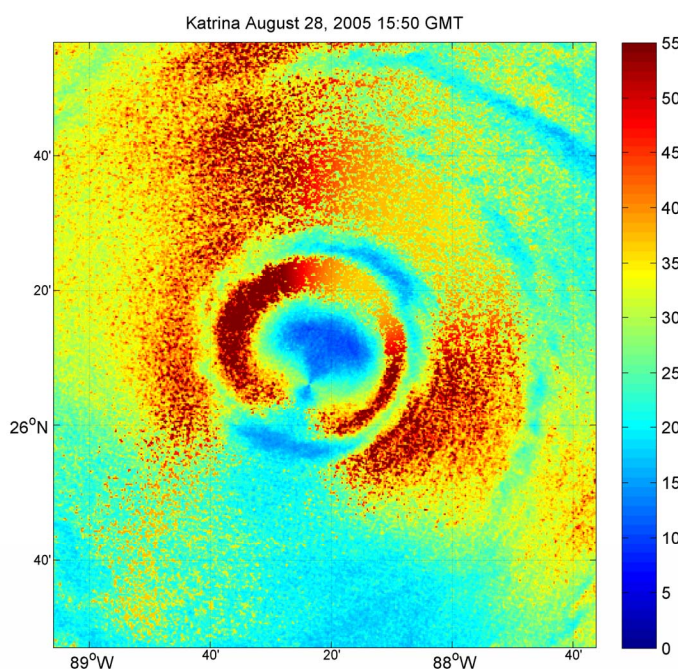
One of the key factors in this project is to produce a “calibrated” SAR image. This is quite a challenging task since different processor produce different quantitative SAR image data. One such artifact is the appearance of “scallop” or straight lines in regular intervals. This will contaminate the extracted wind vectors using any of the wind algorithms. We have developed a new algorithm to descallop image and produce clean SAR data for use in wind algorithms.

Figure 1 shows an example of a contaminated image and then the clean image resulting after application of the “scallop” filter.



**Figure 1: Left: Contaminated SAR image. Second from left: Isolation of scallop artifact in the Fourier domain. Second from right: Correction applied to remove scallop artifact. Right: Clean SAR image after inverse FFT is applied.**

Figure 2 shows a high resolution wind field of Hurricane Katrina. The SAR image clearly defines several morphological features of tropical cyclones such as the center of the eye, the eye wall and the asymmetry of intensity often observed by Hurricane Hunter aircraft. From this wind field the eye diameter and radius of maximum winds can also be deduced as well as other structure features of the hurricane.



**Figure 2: High resolution wind field of Hurricane Katrina derived from RadarSat-1 SAR image collected on 28 August 2005 at 15:50 UTC. Note several morphological features of the storm are readily deduced.**

## **IMPACT/APPLICATIONS**

The new typhoon wind model and complementary sea state and waves algorithm will provide unprecedented information about the intensity and structure of typhoons and hurricanes.

## **TRANSITIONS**

None.

## **RELATED PROJECTS**

None.

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